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T. Attridge

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

LM ENGINEERING MEMO

LMO 541-108
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Rolf Larson
Like I said earlier looks like a perfect run but I gave up one point for ground rules'
TWK

From: LM-3 Data Evaluation Team

To: Distribution

Subject: DETAIL DATA EVALUATION REPORT, LM-3 OCP 61018, RUN BETWEEN 11 MAY AND 13 MAY 1968

Enclosures:
(1) Evaluation Work Sheets
(2) Rendezvous Radar Resolver Signal Flow
(3) Descent Battery Switchover
(4) OCP 61018 LM-3 Current Profile
(5) AC/GAEC-LA 598 "Performance of G&N System 605 during OCP-GF-61018-2-LM-3"
(6) PGNS/AGS Alignment Signal Flow

References:
(a) LM-3 Phase III CARR RFA No. 2.4-4A
(b) LMO 541-107 "Verification of Internally Redundant PCM Channels (RFA No. 2.4-4A, LM-3 Phase III CARR).

Mary Ann
File with LM-3 Incentive FEAT File in E Lanes office

I. SUMMARY

An evaluation of data obtained from the running of OCP 61018 has verified proper LM integrated systems performance during a simulated manned mission.

Nine DAR's were generated and dispositioned during the running of this OCP. An additional three DAR's were generated and dispositioned during the Detailed Data Evaluation (DDE) and do not affect vehicle performance.

All PCM channels were evaluated and found to be satisfactory except for GT0201 S-Band PA RF Power Out, and GH1456 Pitch Attitude Error (externally redundant channel 60). The PCM measurements are listed in the Evaluation Worksheets of Enclosure (1). GT0201 and GH1456 anomalies are described on pages 19 and 20.

MS&E recommendations pertaining to Electrical Power, Flight Control and Instrumentation subsystems are contained in section V of this report.

The results of evaluating MIT/AC GN&C equipment performance are contained in Enclosure (5).

II. A. TEST OBJECTIVES

The test objective of this OCP was the verification of the LM System to perform all functions required during a manned mission. The mission is divided into six phases. These phases are briefly described below:

1. LM Systems Evaluation - This phase of the mission simulates the various modes of supplying power to the LM buses prior to the LM separation from the CSM. Subsequent to switchover from the CSM power to LM power, activation and self test of the LM Subsystems is performed by the Commander and LM pilot.

2. DPS Burns - the simulation of this mission phase is initiated after completion of the LM Systems evaluation. Two descent propulsion burns are performed during this phase. Along with the burns, the Rendezvous Radar, Landing Radar and the Electrical Power Subsystems were also exercised.

3. LM Subsystem Checkout - This phase of the mission includes PGNS and AGS alignment, static check of the RCS and Ascent propellants and selection of Ascent Power and Water. Countdown for the Ascent burns is initiated by the event timer. The Rendezvous Radar is exercised for the simulated tracking of the CSM.

4. Ascent, Rendezvous and Docking -The mission simulation of the ascent burns is initiated by performing the auto ascent profiles. Rendezvous and docking is simulated by; Rendezvous Radar self test, tracking light turn on, RCS X-axis burn, propellants, gases , and fluid checks, EPS status checks and manual operations in attitude and translation control.

5. Post-Docking De-Activation - At the conclusion of the ascent burn, rendezvous and docking phase the docking lights and C-Band transponder are turned off.

6. AGS Abort and Rendezvous - After placing the cabin controls and circuit breakers for a coasting descent configuration, Abort and Abort Stage profiles are initiated. An AGS Autopilot Rendezvous is simulated after the Abort and Abort Stage profiles. All critical functions are monitored in the ACE S/C Control Room and on displays in the LM cabin. Manual operations are performed by the CDR and LM Pilot.

II. B. Real Time Data Evaluation

The test objectives were verified by an evaluation of all available data (PCM, Cabin displays and LDRS) for every sequence of the OCP. This evaluation was performed in the Real Time Data Evaluation (RTDE) room which was staffed 24 hours/day by MS&E personnel and part time by Subsystem and Test Team personnel. All data anomalies

were documented on data anomaly reports (DAR's) and brought to the attention of the test conductor for further action. Status of DAR's and ACE S/C recorder strip chart data evaluation was documented in the DAR and MS&E logs respectively.

III. DISCUSSION

III. A. Flight Control Subsystem (FCS)

OCP 61018 LM-3 has functionally verified the performance of the Flight Control Subsystem parameters. Although all sequences were reviewed the flight control measurements were exercised and evaluated in detail during the following dynamic runs:

- o Seq 36 RGA Checkout
- o Seq 39 RCS Firing Via ACA Checkout
- o Seq 42 AGS Standby
- o Seq 43 AGS Activation and Checkout
- o Seq 49 AGS to PGNS Alignment
- o Seq 57 First DPS Burn
- o Seq 63 Second DPS Burn
- o Seq 65 Manual Functions Associated with Coast DPS Burns
- o Seq 79 Auto Ascent Profiles
- o Seq 87 Command X-Axis RCS Burn - Ascent Burns, Rendezvous and Docking
- o Seq 89 Manual Translation and Attitude Control as per Docking Ascent Burns, Rendezvous and Docking
- o Seq 92 AGS Abort-Abort Stage

1. DPS/APS Burns

An analysis of all FCS data pertaining to the APS and DPS simulated burns indicates satisfactory results. Representative data is documented in Enclosure (1).

2. PGNS/AGS Alignment

A verification of the AGS IMU align capabilities is made by using the AGS and PGNS downlink data and the appropriate LDRS program. This program automatically computes the equation that relate the AGS and PGNS downlink data by calculating the yaw,roll, and pitch attitudes thereby verifying IMU alignment. A comparison

of the expected and actual angle readout is provided in Table I. The PGNS/AGS Alignment signal flow is contained in Enclosure (6).

TABLE I

PGNS/AGS ALIGNMENT COMPARISON

	YAW	ROLL	PITCH
Expected Attitude	30°	-60°	-9°
Attitude calculated from LGC Downlink	30.41	-59.64	-8.44
Attitude calculated from AEA Downlink	30.38	-59.60	-8.45

3. AGS Abort/Abort Stage

The AGS Abort/Abort Stage test, otherwise known as AGS Sim-Flight was used in sequence 92. This test is used as a part of the integrated factory checkout procedure for the AGS subsystem. The AGS Abort/Abort Stage test exercises the AGS flight equations in the major guidance modes in a manner similar to that which would be done in actual flight. The necessary values of gyro and accelerometer scale factor and bias compensations are loaded into the AEA memory prior to initialization of the test. Targeting information for the major guidance modes are loaded into the AEA memory at appropriate times during the run of the test by the LM pilot via DEDA entries. Results of the dry runs of sequence 92 showed that the LM pilot was overburdened with time critical DEDA entries. Modifications were made to the test procedures to permit sufficient time for uninterrupted flow of DEDA inputs. It was also obvious, from the results of the dry runs, that a proper evaluation of the test would be compromised without a detailed profile showing expected results.

Since a profile was not available for data comparison, it was necessary to report as anomalies (DAR 6) those data points which resulted in unexplained and undocumented jet driver outputs.

Two DAR's (numbers 5 and 6) were written against this sequence. A statement of the DAR's is as follows:

DAR #5: When descent batteries high voltage taps indicate "off", jet driver output 4U indicates "ON".

An analysis of the anomalous condition revealed that jet 4U should have been firing and that the pulse immediately preceding the apparent anomaly was missing. The manner of operation exhibited

by jet driver output 4U is attributed to the characteristics of the ATCA/Instrumentation sampling ambiguities as well as variations of the AEA signal output at the time of ABORT STAGE push button operation. A contributing bias was the RGA in phase null (approximately 2o mv). These characteristics are normal. No action is required.

DAR #6: Unexplained behavior of pitch steering errors (GH1456) were observed as follows:

19:47:54 - Steering error goes to zero for no obvious or documented reason.

19:47:56 - Steering error exceeds threshold with attendant jet driver outputs.

19:48:08 - Steering error exhibits noisy output.

19:48:18 - Steering error goes to zero at the time of ABORT STAGE.

19:48:19 - Steering error exceeds threshold with attendant jet driver outputs.

19:48:48 - Pitch steering errors go to zero at time of Auto Eng Off.

19:53:50 - Pitch steering errors exceed threshold with attendant jet driver outputs.

19:54:44 - Steering errors go to zero.

19:54:55 - Steering errors exceed threshold with attendant jet driver outputs (momentarily).

19:54:58 - Steering errors again momentarily exceed threshold with attendant jet driver outputs.

An analysis of the data by MS&E, MA&S, and Systems Test revealed that the AEA correctly responded per the AGS ABORT/ABORT STAGE program. The recommendations resulting from this DAR are contained in Section III A (4).

4. Recommendations

Flight controls data anomalies were discovered during quick look and post test detailed data evaluation. The anomalies, (DAR's 2, 4, 5, 6, 8 and 9) documented in Section IV of this report, have been dispositioned to the satisfaction of NASA, and MS&E. Several action items have resulted from the dispositioned DAR #6. These are listed below.

- The speed of the DEDA operation required by the LM Pilot (LMP) for proper performance of the AGS ABORT/ABORT STAGE profile is time critical and the AEA altitude rate outputs are, at times, too large for processing by the altitude

rate indicator. It is recommended that Mission Analysis and Simulation (MA&S) revise the AGS ABORT/ABORT STAGE program (LM-4 OCP 61018 and subsequent) to reduce the amount of DEDA entries required by the LMP (Established crew response times should be available from Crew Systems.)

- It is recommended that MA&S and Test Engineering include engine on/off profiles, jet driver output profiles and engine gimballing profiles, into the final copy of OCP 61031, LM-4.

- It is recommended that Mission Analysis and Simulation modify the AGS ABORT/ABORT STAGE program such that the attitude errors are of a magnitude to minimize the contribution of computational errors in flight control responses.

III. B. COMMUNICATIONS SUBSYSTEM VERIFICATION

The functional performance of the Communications Subsystem in an integrated configuration was demonstrated. S-Band and VHF Voice capability was demonstrated at the carrier power levels expected during the LM-3 flight (Ref. LMO-541-65). S-Band and VHF data transmission (Hi and Lo Bit Rates) were demonstrated. Ranging and Television transmission was verified. Finally, a DCA-LGC Interface check was made. Although OCP 61018 has verified Communications Subsystem capability, there are six DR's pertaining to communications which will have to be dispositioned prior to the flight.

During the Subsystem Verification, OCP 38037, three DR's were generated. (Reference LMO 541-93).

- <u>DR #90</u>: With the PM/FM switch in the FM position and either Emergency Key or Backup Voice selected, the system automatically switches to PM. A procedural step of cycling the PM/FM switch to PM and back to FM again will establish the normal configuration.

- <u>DR #95</u>: S-Band Power Amplifier RF Power (GT0201) readouts are out of limits. This was caused by a bad transducer on the PA. ERA-2, the S-Band Power Amplifier and Diplexer, will be replaced at KSC.

- <u>DR #100</u>: GSE and Flight Hardware incompatibility. The FM Test Receiver in the CTS*is not capable of demodulating the large frequency deviations present during TV transmission, i.e., the demodulation bandwith is insufficient. OCP 61018 utilized another receiver, with sufficient demodulation bandwith, and TV reception was acceptable. However since signal plus noise to noise ratios were not determined as required in OCP 38037, this DR is still open.

*CTS = Communication Test Stand

During OCP 61015, three DR's were issued pertaining to the Communications Susbystem (Reference LMO 541-98).

- DR #102 and #138: Excessive noise on the Flight Headsets was exhibited on both S-Band and VHF. This was caused by varying the Anun/Num Lighting Rheostat on Panel 5. It appears that when the voltage across the potentiometer is less than 2 volts, the LCA goes into oscillation. A possible solution under study is to add a limiting resistor to assure voltages of greater than 2 volts across the pot. The problem is presently under study by the EMI group, Vehicle Test Team, and the LCA vendor.

- DR #132: The VOX Control for the DSEA sees a continually "hot" CDR mike output, thus the tape recorder is not capable of being turned off. The Signal Processor Assembly (ERA-4) will be replaced at KSC to disposition this DR.

Since there are still six DR's which have to be dispositioned, the Communications Subsystem cannot be classified as flight-ready. Two ERA's will have to be replaced, and additional testing will have to be performed at KSC prior to the flight.

III. C. RADAR PERFORMANCE VERIFICATION

An evaluation of the data for the LM-3 Rendezvous Radar and Landing Radar (LR), as prescribed by OCP 61018, disclosed that both Radars functioned within their scope of operation. No anomalies were detected for the Landing Radar. Two post-test detailed data evaluation (DAR's NO.'s 10 and 11) were issued pertaining to the Rendezvous Radar. These DAR's do not affect Rendezvous Radar performance.

1. Landing Radar Verification

Landing Radar performance evaluation encompassed the verification of Self-Test, Manual Tilt, Automatic Tilt (LGC via verb 45 insertion through the DSKY) and LR/LGC Interface Verification, i.e., Landing Radar and LGC processing of simulated Altitude values and velocity vectors (V_X, V_Y, and V_Z).

Self Test was verified by the proper readouts of the velocity and altitude data as determined from cabin meters, which were within the specification values defined. The results of the evaluation are summarized in Table II.

TABLE II

SELF-TEST VERIFICATION

Meas No.	Source	Measurement Description	Units	Recorded Value	Limits
GN7523	9M9B	Altitude Rate	fps	+450	-443 to -457
GN7524	9M2/3	Lateral Velocity	fps	+200	+200 min*
GN7525	9M2/3	Forward Velocity	fps	+200	200 min*
GN7527	9M9A	Altitude	ft	8290	8100 to 8450

* meters pegged

In addition, the LR/LGC Interface was verified during Self-Test. This encompassed a comparison of simulated Altitude values and velocity vectors as shown in Table III.

TABLE III

VERIFICATION OF LR/LGC INTERFACE DURING SELF-TEST

Description	Units	Limits	Recorded Value			
			CRT	DSKY	LGC Downlink	Cabin Meter
Altitude	feet	8156 to 8418	8286	8281	8277	8290
V_X	fps	-228 to -266	+246*	+246*	+246.5*	**
V_Y	fps	934 to 990	961	961	960.7	**
V_Z	fps	630 to 686	658	657	658	**

* Scale factor is -1 due to anomaly in Aurora 88 program.

** Cabin Display Meter readouts cannot be correlated with CRT, DSKY, LGC Downlink values because of a modification ot the LM-3 Landing Radar. That is, the velocity data entering the meters is processed to reflect true velocities, while the velocity vector data (V_X, V_Y, V_Z) is unprocessed velocity data. This change was implemented in order to determine if extraneous signals would effect radar operation during the flight (Reference LMO 541-71).

Analysis of all the data taken during the Self-Test Mode reveals that the LM-3 Landing Radar is capable of meeting all the requirements of the Self-Test functions. In addition, the antenna tilt mechanism and the associated control circuitry was verified during both manual tilt and LGC commanded tilt.

The LGC commanded tilt from descent to hover was accomplished in 6.3 seconds which is within tolerance (10 seconds). The above was verified using DFI data.

2. Rendezvous Radar Verification

Rendezvous Radar performance evaluation encompasses the verification of the Self-Test, Auto Track and LGC Designate modes of operation. In addition, antenna slew rate and the Rendezvous Radar/LGC Interface was verified. Two TDR's and two DAR's were issued, which are discussed in Section (e).

a. Self-Test (Auto Track) Verification

The operation of Self-Test was verified during the RR Auto Track Mode of operation. Similated values of range and range rate were inserted to permit quantitative checking via the displays. The data is summarized in Table IV.

TABLE IV

SELF-TEST VERIFICATION

Meas. No.	Source	Measurement Description	Units	Recorded Value	Limits
GN7613	9M9A	Range	NM	193	189 to 198
GN7614	9M9B	Range Rate	fps	-472.25	-459 to -541
GN7644	17M1	ATM Output (Trunnion)	VDC	2.1 2.9	0.0 to 2.5 1.5 to 3.5
GN7646	17M1	ATM Output (Shaft)	VDC	2.1 2.9	0.0 to 2.5 1.5 to 3.5
GN7642	17M1	Transmitter Power	VDC	3.4	2.1 to 4.8
GN7648	17M1	ATM Output (AGC)	VDC	1.25	0.7 to 3.0

b. Slew Rate Verification (Manual Mode)

Slew Rates are verified by determining the speed with which the antenna motion responds to manual slew commands. Table V shows a comparison of data as determined from the cabin meters and from the ACE Strip Charts.

TABLE V

SLEW RATE VERIFICATION

Slew Direction	Sequence	Elevation or Azimuth Rate (9M2/3) Milliradian/Sec	Elevation or Azimuth Rate (9M2/3) mr/sec converted to deg/sec	Slew Rate Determined from ACE Strip Chart (4A1A3)deg/sec
Shaft Up (Lo)	45-015	3.5	1.17	0.9
Shaft Down(Lo)	45-019	2.9	0.98	0.66
Trunnion Right (Lo)	45-021	3.2	1.08	0.69
Trunnion Left (Lo)	45-024	2.8	0.94	0.39
Trunnion Hi	45-026	Not Recorded	N/A	4.1
Shaft Hi	45-026	Not Recorded	N/A	14.2
Shaft Op(Lo)	82-014	3	1.01	1.5
Shaft Down(Lo)	82-016	3	1.01	1.84
Trunnion Right (Lo)	82-019	3	1.01	2.2
Trunnion Left (Lo)	82-023	2.9	0.98	1.76

The Radar Spec (LSP 370-2F) requires a High Slew Rate of 7 deg/sec minimum and a Low Slew Rate being nominally 1 deg/sec. Table V shows that the low slew rates, as determined from the cabin meters 9M2/3, were as expected. Post Test evaluation, utilizing the 1X Resolver outputs recorded on 4 A1A3, yield erratic slew rates, therefore DAR #10 was issued. This DAR was caused by an incompatibility between MIT signal conditioning equipment and the resolver excitation (See section IIIC 2(e)). This is a normal RR/LGC interface behavior during the Auto Track Mode.

c. LGC Designate Mode Verification

When switch 17S3 is placed in the LGC position, the Designate Mode is activated. During this mode the Rendezvous Radar antenna motion is governed by LGC commands. Data analysis reveals that the antenna followed the LGC commands, i.e., it moved to the designated positions at the proper rates (1.7 deg/sec low slew rate and 10.6 deg/sec Hi slew rate). For a comparison of antenna angular position as determined from the CRT, LGC Dump and Strip Chart data, see TableVI in Section III C 2(d).

d. Rendezvous Radar/LGC Interface

The RR/LGC interface was verified by comparing the data obtained from the DSKY and LGC Downlink with the CRT, Cabin Meter, and Strip Chart values. Tables VI and VII summarize the data.

TABLE VI

RR/LGC INTERFACE - ANTENNA ANGULAR POSITION IN DEGREES

Description	CRT Reading	LGC Downlink	Strip Chart	Limits
Trunnion Angle	304.99	304.98	311	304.7 to 305.3
Shaft Angle	310.07	310.06	313	309.7 to 310.3
Trunnion Angle	359.98	359.98	0.51	359.7 to 0.3
Shaft Angle	0.03	0.03	0.1	359.7 to 0.3

TABLE VII

RR/LGC INTERFACE - RANGE AND RANGE RATE

Description	Cabin Meter (9M9A/B)	DSKY	LGC Downlink	Limits
Range (NMl)	193	193.5	193.5	189 to 198
Range Rate(FPS)	-472.3	+473*	-473	-459 to -541

* Range Rate as displayed on DSKY is of opposite polarity to that of the Cabin Meter and LGC Downlink because of an erroneous scale factor in the Aurora 88 program.

Analysis of the data for both tables reveals very good agreement between data processed by the LGC and data processed by the Rendezvous Radar. There is a slight discrepancy between the antenna angular position as determined from the strip chart and from the LGC. This is to be expected for the following two reasons:

1. Data on the strip charts was determined from the 1X resolver outputs. The data processed by the LGC uses both the 16X and 1X resolver outputs, both sine and cosine windings. Therefore, the LGC data is more accurate.

2. Interpretation of the data on the strip charts necessitates the use of calibration data and arithmetic manipulation. That is, the data is in Volts DC. This has to be converted to VRMS by calibration curves. The following equation then has to be utilized:

$$\text{Angle} = \sin^{-1} \frac{\text{VRMS}}{\text{V Reference}}$$

V Reference is 28 VRMS ± 5%.

This method of determining angular position is inaccurate compared to the LGC output, but it can be used quantitatively to determine an "approximate" angular position of the antenna.

e. Summary of R/R Test Discrepancy and Data Anomaly Reports.

Two TDR's and two DAR's were issued against the Radar for this test. The two TDR's and two DAR's are considered closed although DAR #11 does not have a conclusive disposition. A brief description of the anomalies follows:

- TDR #12: When the LGC designated the antenna to -55 degrees in Trunnion, data showed the antenna to be at +16.9 degrees. The sine and cosine resolver output signals were also missing from the CRT.

  It was determined that the PGNS 28V 800 Hz reference signal was not present at the resolvers. Subsequent investigation revealed that the loss of the PGNS 800 Hz signal was caused by "stressing" the Mode Select switch (17S3) to its stop, thus, open-circuiting the 800 Hz line. Final disposition of this TDR was that the observed switch action is characteristic of this type of multi-wafer rotary switch and does not constitute a defective component. The sequence was rerun successfully.

- TDR #15: When displaying range data on the DSKY, a readout of 0 was obtained.

  The LGC program used to interrogate the Rendezvous Radar for Range and Range Rate has a safeguard such that data will not be displayed if the antenna is outside the program limits (Mode 1: ±70 deg in trunnion, +60 -70 deg in shaft). The LGC's knowledge of antenna position comes from the CDU which derives the angle from the antenna resolvers. In the LGC mode the resolvers are excited with the PGNS 28 VRMS, 800 Hz signal. However, in the Auto Track mode the resolvers are excited with 15 VRMS, 800 Hz from ATCA. Consequently, the angles derived by the CDU with the RR in the Auto Track Mode

are in error. The CDU angles, which the LGC received, were out of the program limits because of this "false" indication. Therefore, the LGC could not process the Range information during the Auto Track.

In order to display Rendezvous Radar Range information the LGC must have an antenna angular position indication from the CDU that the antenna is within its program limits. By proper code insertion through the DSKY, a "false" antenna angular position from the CDU (0,0) was simulated, thus the LGC "thought" it was within its program limits. The data thus obtained was acceptable. Since the normal mode of operation is with the 28 Volt reference, i.e., 17S3 in LGC position, this is not a problem.

o DAR #10: Measurements GG3304, GG3305, GG3324 and GG3325, the 1X Resolver Outputs as processed by MIT signal conditioning equipment were utilized to determine the antenna manual slew rates. These slew rates were erratic and out of the specified limits (See Table V, slew rate verification, Page 10).

During the Manual Slew Mode, the Radar utilizes the 15 VRMS. 800 Hz reference signal from the ATCA. The PGNS 28 VRMS, 800 Hz reference signal is utilized when the Radar is in the LGC mode. The slew rates during LGC Designation were as expected.

The slew rates in the Manual Slew Mode were in error because of an incompatibility between the MIT Signal Conditioning Equipment and the ATCA 15V 800 Hz Resolver Excitation (See Enclosure 2). The PGNS and ATCA 800 Hz signals are not phase synchronized to each other, and hence a random phase difference exists between the resolver output and the demodulation reference signal in the MIT SCEA (Manual slew mode). In the LGC mode the MIT/SCEA and the Resolvers references are from the same supply, precluding an incompatibility. Consequently, the 1X Resolver data is only meaningful with 17-S-3 in the LGC position.

Since Auto Track Mode is a back-up mode, to be utilized in case of an LGC failure, the incompatibility should not occur during flight. In the Manual Slew Mode, the slew rates can be determined from cabin meters 9M2/3 if desired. Since determination of slew rates is not a mission objective, this incompatibility does not take on critical proportions.

- DAR #11: While the RR Antenna was in the stowed Position, the 1X Resolver Output signals show a sudden change in position of about 12 degrees in shaft. The antenna maintained this position for 3 minutes, 5 seconds and then suddenly came back to "about" its original position. Discussions with the Radar Tech on station at the time revealed that as far as he knows, the antenna was not moved at this time, it was mechanically pinned in the stow position.

  There is no known reason for this anomaly, especially since the Rendezvous Radar was off at this time and the antenna was mechanically clamped to its stowed position. However, some possible causes for this anomaly are ennumerated below:

  1. Some one inadvertently moved the antenna
  2. Instrumentation Path Problem (Non-repetitive)
  3. Sudden change in phase relationship between PGNS 800 Hz Reference and ATCA 800 Hz Resolver Excitation (See Enclosure 2).

III. D. PROPULSION AND RCS

The results of data evaluation (Enclosure (1)) have indicated proper functional operation of the Propulsion and RCS subsystem. The basic checkout consisted of:

1. Functional operation of the Caution and Warning.
2. Verification of Fuel/Oxidizer pressure and temperature transducer under ambient conditions.
3. Verification of cabin display and controls.
4. Verification of RCS quad heater control.
5. Functional operation (simulation) of the PQGS Control Unit.
6. Verification of Valve position indicator.

Control functions such as descent engine gimballing, throttling and RCS jet firing are described under Flight Control Subsystem, Paragraph III A.

Erroneous flag displays were reported on TDR #16. This was caused by an "out of vehicle configuration" which resulted from troubleshooting a GSE TDR #9. No DAR's were generated.

III. E. ENVIRONMENTAL CONTROL SUBSYSTEM (ECS)

1. Heat Transport Section (HTS)

The function of the HTS is to provide thermal control of the LM equipment. A redundant loop provides thermal control if a failure of both pumps in the primary loop occurs. Both loops were verified to function properly during the following operation:

- o Glycol pump checkout in both primary and secondary loops.
- o Automatic pump switchover.
- o Glycol accumulator low level checkout.
- o Verification of loop temperature and pressure.
- o Verification of Caution and Warning indicator.

DAR #3 was generated against the HTS. This DAR was subsequently transferred into TDR #21 and was dispositioned as follows:

- o Erroneous operation. The glycol bleed valve was erroneously placed to fully open causing an excessive glycol loop pressure decay. This excessive pressure decay could not be accomodated by the glycol accumulator and consequently resulted in a low discharge pressure (GF9997) value when the glycol caution light illuminated. A within tolerance pressure at the time of the caution light indication was observed when the glycol bleed valve was correctly cracked open to allow a controllable pressure drop.
- o Erroneous tolerance range. The OCP limits of 22 to 26 PSIA, which are determined from ambient pressure, head pressure of the liquid, and the accumulator spring constant, were recalibrated. New OCP limits of 20 to 24 PSIA were established and incorporated in the OCP.

2. Atmosphere Revitalization (ARS)

The ARS provides suit/cabin cooling and ventilation. These functions were verified during the following operations:

- o Suit fan checkout in normal mode.
- o LiOH cannister selection in normal and egress modes.
- o Suit gas deverter valve operation.
- o Suit isolation valve operation.

DAR #7 was generated against the ARS. This DAR was subsequently transferred to TDR #20 then to DR #136 and was dispositioned as follows:

o <u>Disposition of the ECS caution</u> indication was observed for a low suit fan Δ P(GF1083) discrete. The caution indication occurred when the suit fan switch (7S1) was placed in pump 1 position and the low suit fan Δ P (GF1083) discrete was inhibited by a previous deactivation of the Δ P circuit breaker 4CB120. The anomalous illumination of the ECS Caution light is due to the charging of the capacitor across the relay contact which inhibits the low suit fan Δ P (GF1083) signal. The capacitor charging effect will not present itself during flight because normal suit fan switchover with 7S1 is accomplished with the Δ P circuit breaker 4CB120 in a closed configuration. Circuit breaker 4CB120 controls the relay contact which inhibits the low suit fan Δ P (GF1083) signal (Reference LAV 330-769).

3. Water Management Section (WMS)

Satisfactorily operation of the WGS was demonstrated for the following:

- Ascent/descent Water Tank Quantity simulation.
- Water pressure regulators (Δ P between reg outlet and ARS suit inlet).
- Water separator rates.
- Water tank selector valve operation.
- Verification of Caution and Warning.
- Water crossover solenoid valve operation.

The water crossover solenoid valve (TDR #11) was found in the closed position which resulted in an out of limits reading for GF4102 (Δ P between the secondary water regulator outlet and suit loop pressure). At the time of the TDR, a primary water regulator failure was being simulated to verify the operation of the secondary water regulator. This simulation entailed the opening of the primary evaporator valve (7H16) to allow the secondary water regulator to regulate to approximately 15.7 PSIA (ΔP of 0.5 to 1.0 PSID) above suit loop pressure. However, the gas which was used to simulate water, leaked across the regulators* and was trapped between the tanks and the closed crossover valve. This trapped gas pressure eventually built up to approximately 30 PSIA which resulted in an out of tolerance condition for the Δ P between the secondary regulator

* No specification exists for the use of gas as a medium for the water regulator.

outlet and the suit loop pressure (GF4102). The sequence was successfully rerun after the vehicle was placed in the proper configuration i.e. by opening the water crossover solenoid valve.

4. Oxygen Supply and Cabin Pressure Control Section (OSCPCS)

The OSCPCS stores in gaseous form all the oxygen to maintain suit, and cabin pressures as required. Oxygen is supplied as needed to replenish losses due to crew metabolic consumption and cabin or suit leakage.

The operations which were performed to verify the OSCPCS function were:

- Ascent/descent oxygen tank quantity simulation

  Asc O_2 tank 1 - GF3582Q

  Asc O_2 tank 2 - GF3583Q

  Desc O_2 tank - GF3584Q

- O_2 demand regulator - selection of (Close-Direct O_2 - Cabin - Egress).

- Associated caution and warning indications.

The O_2 tank pressure were simulated thru GSE connects by gaseous nitrogen and instrumentation readings were verified in limits as shown in evaluation sheets.

III. F. ELECTRICAL POWER SUBSYSTEM (EPS)

EPS performance was satisfactory throughout the OCP 61018-LM-3 test. The AC and DC voltages, DC currents and frequency was monitored on analog strip charts, and the discretes on event recorder strip charts. The strip chart data was compared to data from the QC and LDRS annotated OCP copies and to LDRS Com-Gen compacted data to verify proper performance under varying and steady state load conditions.

Plugs-out power for the vehicle was provided by six silver zinc primary batteries. The two ascent batteries were each 20 cell, three hundred ampere hour units. The four descent batteries were each 20 cell four hundred ampere hour units tapped at the 17th cell to provide a reduced voltage for the initial part of the simulated mission and OCP testing. Three reverse current malfunction indicators were activated during the switchover from low voltage taps to high voltage taps. This does not constitute a failure since the malfunction indication would respond under certain conditions of voltage and current if switchover is not completed within a few seconds. The operation of these malfunction indications merely re-verified their ability to respond to proper stimuli. Strip chart and LDRS data verified satisfactory switchover.

Enclosure (3) shows the switchover as recorded on the battery current chart. It should be noted that the current sensors in Enclosure (3) are not phase sensitive.

The current profile, Enclosure (4), shows the EPS predicted currents and current measurements recorded on the strip charts during the OCP sequences. The differences between the predicted and the test levels are attributed to "last minute" procedural changes during test. Enclosure (4) was provided through the courtesy of Design Engineering, Electrical Power Subsystem.'

Two TDR's and one DAR were generated during the OCP.

- TDR #2 Initiated early switch over from the battery low voltage taps to the high voltage taps. Low bus voltages (26.8 VDC) was exhibited early in the OCP. Low bus voltage was attributed to battery age.
- TDR #4 Vehicle was out of configuration because of early battery switchover (TDR #2). Switchover to CSM power must be accomplished using the low voltage tap configuration.
- DAR #1 While switching from low voltage to high voltage battery taps (TDR #2), a reverse current indication was observed. Currents after switchover of battery 1 were as follows:

BAT 1	60 amps (F.S. on recorder)
BAT 2	19.2 amps reverse current
BAT 3	9.3 amps reverse current
BAT 4	9.7 amps reverse current

Maximum reverse currents during switchover were

BAT 1	None
BAT 2	19.2 amps (BAT 1 on HV taps)
BAT 3	24.0 amps (BAT 1 and 2 on HV taps)
BAT 4	51.0 amps (BAT 1, 2 and 3 on HV taps)

Maximum current on BAT 1 during switchover was 62.2 amps. This occurred when BAT 2, 3 and 4 were drawing reverse current and the vehicle load was 24 amps. The above phenomena - excessive current on BAT 1 and reverse current on BAT 2, 3 and 4 - was normal and anticipated per LMO 541-53. MS&E recommends that Crew Systems provide procedural changes to the AOH alerting the LM Crew of this condition.

III. G. EXPLOSIVE DEVICES SUBSYSTEM (EDS)

The only EDS measurements available via PCM are GY0201, GY0202, GY0231 and GY0232. While these measurements are recorded on the evaluation work sheets as having been evaluated only at specific

OCP sequences, they have in fact been evaluated throughout the entire OCP.

GY0201 and GY0202 monitor the Master Arm and stage sequence relays of System A and B respectively. The monitoring controls of these relays are arranged in a series parallel configuration. If any one, or combination, of these relays operates inadvertently, their telemetry signal does not distinguish which relay or relays are at fault. But, with prior knowledge of the OCP procedures, the proper GY0201 and GY0202 indication can be determined. If the indications are not as expected one can not determine from the data what has happened but it does give reason for investigation.

GY0231 and GY0232 monitor the remaining firing relays (K7 then K15) of each system. The monitoring contacts of these relays are arranged with their normally closed contacts in a series daisy chain. The normal indication is an On (one). An off indication will not give information as to which relay was fired but again with a prior information of the OCP procedures one can determine the expected On or Off indication.

Review of GY0201, GY0202, GY0231 and GY0232 throughout the OCP revealed the expected indications in support of the procedures performed.

III. H. INSTRUMENTATION

All measurements tested individually by subsystem involved the signal processing functions of instrumentation, and thus constituted a test of the instrumentation subsystem itself. A total of 121 analog and 130 discrete measurements were tested during OCP 61018*; 28 analog and 5 discrete measurements were covered by AC Electronics Corporation (Enclosure (5)). Although not all of the transducers could be given a full range of stimuli (e.g., fuel quantity, thrust chamber pressure), all PCM telemetered measurements were investigated for at least the proper static value during the OCP. The evaluation worksheets are attached to this report as Enclosure (1).

All measurements tested were found to be within limits except for the following:

- o GT0201 S-Band PA RF Power Out - The S-Band power amplifier (ERA #2) transducer for GT0201 was found to malfunction under certain conditions (see Communications Section, paragraph III C of this report and DR #95).

* Internally and externally redundant measurements were evaluated during the post test detail data evaluation in reply to Reference (a).

- GH1456 Pitch Attitude Error - A review of internally and externally redundant PCM channel data for a ten second time slice during this OCP verified proper operation of all channels with the exception of GH1456, the externally redundant channel 60 (Prime Frame 16, Word 101). MS&E recommends that the above channel be monitored at KSC and if found defective, removed as an active channel (Reference (B)). The measurement will not be lost because it is also contained on internally channels seven and forty-two. This anomaly is described in DAR #12.

The Caution and Warning Electronics of the Instrumentation subsystem were used throughout the OCP to verify caution and warning signal inputs and master alarm activations. There were 89 master alarm actuations (GL4069) during the OCP, none of which indicated malfunction of the CWEA. There were no unexplained master alarms. Two of the master alarm actuations were caused by electromagnetic interference when the docking lights were turned on and Rendezvous Radar Heater Caution was erroneously indicated. This anomaly is described in TDR #1.

IV. SUMMARY OF DATA ANOMALY REPORTS (DAR)

A total of twelve DAR's were generated against this OCP. Nine were generated during Real Time Data Evaluation (RTDE) and the remaining three during the post test Detailed Data Evaluation (DDE). These DAR's are summarized below.

DAR 1 Description - Reverse current indication on descent batteries 2, 3 and 4 (GC1202, GC1203 and GC1204) during high voltage switchover.

Disposition - Normal operation. See recommendation under paragraph III F.

DAR 2 Description - Erroneous Roll RG Sig (GH1463) indication during ATCA circuit breaker (4CB82) closure.

Disposition - Improper setting of ACE S/C Control Room recorder sensitivity. No action required.

DAR 3 Description - Erroneous Glycol Pump Discharge Pressure (GH9997) indication at time of Caution and Warning light activation.

Disposition - Transferred to TDR #21. Operator error. Glycol accumulator bleed off was too rapid. No action required.

DAR 4 Description - Erroneous Yaw, Pitch and Roll Attitude Error (GH1455, GH1456, and GH1457) indications during AGS standby/operate switchover.

Disposition - AEA output registers are in a random state at time of AGS switchover from standby to operate. Normal operation. No action required.

DAR 5 Description - One pulse of a 4U jet (GH1418) pulse train was missing, at the time of ABORT STAGE push button operation.

Disposition - The apparent anomalous behavior is attributed to the ATCA/Instrumentation sampling ambiguities and the near threshold value of the AEA signal output at the time of the ABORT STAGE push button operation. No action required.

DAR 6 Description - Unexplained behavior of PITCH Attitude Error (GH1456) signal

Disposition - Normal operation of the AEA. The steering errors are a function of the steering computations. Attitude errors should be of sufficient magnitude to minimize the effect of mathematical errors. Limit time critical DEDA operation. See recommendations under paragraph III A.

DAR 7 Description - Erroneous Prime Suit Compressor Fail (GF1083) indication.

Disposition - Transferred to TDR #20 and DR #136

DAR 8 Description - A one hundred millisecond time differential appears between jets 4D (GH1419) and 4U (GH1419) firings.

Disposition - The apparent time differential results from ACE S/C recorder resolution. No action required.

DAR 9 Description - Unexplained jet firing (GH1420/GH1421) appears on ACE S/C recorder 5A1A2.

Disposition - ACE S/C recorder 3A2A5 and LDRS data does not verify jet firing. No action required. ACE-S/C Control Room malfunction.

DAR 10 Description - Calculations for the slew rates of the RR yield out of tolerance and very erratic results.

Disposition - Incompatibility between Radar output and MIT signal conditioning equipment. No action required. See page 13 for explanation).

DAR 11 Description - While the RR was in the stowed position, data shows that the antenna unexpectedly moved about 12 degrees.

Disposition - Radar was off at this time, therefore, antenna "apparent" movement unexplainable. For possible causes, see page 14.

DAR 12 Description - Erroneous externally redundant Channel 60 data for Pitch Attitude Error (GH1456).

Disposition - Monitor at KSC and delete from PCMTEA loading list if defective. See recommendation under paragraph III. H.

V. CONCLUSIONS & RECOMMENDATIONS

An evaluation of the data verified proper LM integrated systems performance during a simulated manned mission.

All DAR's were successfully dispositioned.

MS&E recommends the following action as a result of DAR's 1, 6, and 12:

A. Crew Systems (Reference paragarph IIIF and DAR #1)

- Three battery malfunction indications, because of reverse current, were activated during the switchover from LV to HV battery taps. All three batteries returned to normal by the completionof the switchover. It is recommended that Crew Systems add a note to the ACH alerting the crew to the possible battery malfunction indication during battery switchover (For LM-3 only).

B. Mission Analysis and Simulation (Reference paragraph III A and DAR #6)

- The speed of the DEDA operation required by the LMP for proper performance of the AGS ABORT/ABORT STAGE profile is time critical and the altitude rate outputs by the AEA are too large at times for the altitude rate indicator to process. It is recommended that Mission Analysis and Simulation revise the AGS ABORT/ABORT STAGE sequence of DEDA entries. LM-4 OCP 61018 and subsequent to reduce the amount of DEDA entries required by the LMP.

- It is recommended tha Mission Analysis and Simulation and Test Engineering include engine on/off profiles, jet driver output profiles and engine gimballing profiles in all subsequent OCP's utilizing the AGS SIM-FLIGHT program.

- It is recommended that Mission Analysis and Simulation modify the AGS ABORT/ABORT STAGE program such that the attitude errors are of a magnitude to minimize the contribution of computational errors in flight control responses.

C. KSC Test Operation (Reference paragraph III H and DAR #12)

- A review of redundant PCM channel data during post test DDE revealed that the externally redundant channel 60 (GH1456 Pitch attitude Error) has malfunctioned. It is recommended that KSC Test Operation monitor the above channel and if found defective, initiate the paperwork to remove it as an active channel from the PCMTEA Loading List.

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